

WHAT IS CLAIMED IS:

1. A pulsed fiber laser outputting pulses having a duration and corresponding pulse width comprising:

a modelocked fiber oscillator outputting optical pulses;

an amplifier optically connected to said modelocked fiber oscillator to receive said optical pulses, said amplifier comprising a gain medium that imparts gain to said optical pulses; and

a variable attenuator disposed between said modelocked fiber oscillator and said amplifier, said variable attenuator having an adjustable transmission such that said optical energy that is coupled from said modelocked fiber oscillator to said amplifier can be reduced; and

a compressor to compress the pulse to reduce the pulse width.

2. The pulsed fiber laser of Claim 1, wherein said variable attenuator comprises a polarization selection optics.

3. The pulsed fiber laser of Claim 2, wherein said variable attenuator comprises a polarizer.

4. The pulsed fiber laser of Claim 3, wherein said variable attenuator further comprises a polarization rotation element.

5. The pulsed fiber laser of Claim 4, wherein said polarization rotation element comprises a waveplate.

6. The pulsed fiber laser of Claim 1, wherein said variable attenuator comprises one or more optical elements contained in a housing having input and output fibers extending therefrom for coupling light through said one or more optical elements.

7. The pulsed fiber laser of Claim 1, further comprising a pulse compressor optically coupled to receive said amplified optical pulses output from amplifier, said pulse compressor comprising one or more dispersive optical elements that shorten the duration of said optical pulse output by said fiber amplifier.

8. The pulsed fiber laser of Claim 7, wherein said one or more dispersive optical elements comprises a dispersive optical fiber.

9. A method of producing compressed high power short laser pulses having an optical power of at least about 200 mW and a pulse duration of about 200 femtoseconds or less, said method comprising:

substantially mode-locking longitudinal modes of a laser cavity to repetitively produce a laser pulse;

amplifying said laser pulse;

chirping said laser pulse thereby changing the optical frequency of said optical pulse over time;

compressing said laser pulse by propagating different optical frequency components of said laser pulse differently to produce compressed laser pulses having a shortened temporal duration; and

selectively attenuating said laser pulse prior to said amplifying of said laser pulse to further shorten said duration of said compressed laser pulses.

10. The method of Claim 9, wherein said laser pulses are attenuated by between about 1 to 20 dB.

11. The method of Claim 9, further comprising substantially maintaining the polarization of said laser pulse after said amplifying until said compressing of said laser pulses.

12. A method of manufacturing a high power short pulse fiber laser, said method comprising:

mode-locking a fiber-based oscillator that outputs optical pulses;

optically coupling an amplifier to said fiber-based oscillator through a variable attenuator so as to feed said optical pulses from said fiber-based oscillator through said variable attenuator and to said amplifier; and

adjusting said variable attenuator based on a measurement of said optical pulses to reduce the intensity of the optical pulses delivered to said amplifier and to shorten said pulse.

13. The method of Claim 12, further comprising optically coupling a pulse compressor to said amplifier to shorten said optical pulses.

14. The method of Claim 12, further comprising pumping said amplifier to amplify said optical pulses from said fiber-based oscillator and compressing said optical pulses, said optical pulses after said amplifying and compressing having an average power of at least about 200 mW and a pulse duration at least as short as 200 femtoseconds.

15. The method of Claim 12, wherein said variable attenuator is adjusted based on a measurement of the power of said optical pulses.

16. The method of Claim 12, wherein said variable attenuator is adjusted based on a measurement of the pulse duration of said output pulses.

17. The method of Claim 12, further comprising packaging said attenuator in a sealed housing.

18. The method of Claim 12, further comprising packaging at least a portion of said oscillator in a sealed housing.

19. A pulsed fiber laser outputting pulses having a pulse width, said pulsed fiber laser comprising:

a modelocked fiber oscillator producing an optical output comprising a plurality of optical pulses having a pulse width and a spectral power distribution having a bandwidth;

an amplifier optically connected to said modelocked fiber amplifier for amplifying said optical pulses; and

a spectral filter disposed to receive said optical output of said modelocked fiber oscillator prior to reaching said amplifier, said spectral filter having a spectral transmission with a band edge that overlaps said spectral power distribution of said optical output of said modelocked fiber oscillator to attenuate a portion of said spectral power distribution and thereby reduce the spectral bandwidth, the pulse width of said optical pulses coupled from said mode lock fiber oscillator to said fiber amplifier thereby being reduced.

20. The pulsed fiber laser of Claim 19, wherein said spectral filter comprises a filter selected from the group consisting of a bandpass filter, a low pass filter, and a high pass filter.

21. The pulsed fiber laser of Claim 19, wherein said spectral filter comprises a bandpass filter.

22. The pulsed fiber laser of Claim 19, wherein said spectral filter has a spectral bandwidth of between about 5 and 12nm.

23. The pulsed fiber laser of Claim 19, wherein said spectral filter comprises a grating.

24. The pulsed fiber laser of Claim 19, wherein said spectral filter comprises a long period fiber Bragg grating.

25. The pulsed fiber laser of Claim 19, wherein said spectral filter reduces the spectral bandwidth by between about 5 to 12nm.

26. The pulsed fiber laser of Claim 19, wherein said spectral filter is disposed in a housing having input and output fibers that couple optical output of said modelocked fiber oscillator through said spectral filter.

27. A method of producing compressed optical pulses, said method comprising:

substantially mode-locking longitudinal modes of a fiber resonant cavity so as to produce a train of optical pulses having a corresponding spectral power distribution with a spectral bandwidth;

amplifying said optical pulses;

compressing said optical pulses to produce compressed optical pulses;

and

reducing the spectral bandwidth of said spectral power distribution such that said compressed optical pulses have a shorter duration.

28. The method of Claim 27, wherein said spectral bandwidth is reduced prior to amplifying said optical pulses.

29. The pulsed fiber laser of Claim 27, wherein said spectral bandwidth is reduced by between about 5 to 12 nm.

30. The pulsed fiber laser of Claim 27, wherein said spectral bandwidth is reduced to less than about 10nm.

31. A pulsed fiber laser comprising:

a modelocked fiber oscillator comprising a gain fiber and a pair of reflective optical elements disposed with respect to said gain fiber to form a resonant cavity, said modelocked fiber oscillator producing a train of optical pulses having an average pulse width;

an amplifier optically connected to said modelocked fiber amplifier such that said optical pulses can propagate through said amplifier, said fiber amplifier amplifying said optical pulses;

one or more optical pump sources optically connected to said modelocked fiber oscillator and said fiber amplifier to pump said fiber oscillator and fiber amplifier;

a pulse compressor optically coupled to receive said amplified optical pulses output from fiber amplifier, said pulse compressor shortening the pulse width of said optical pulses output by said fiber amplifier; and

a pre-compressor disposed in an optical path between said modelocked fiber oscillator and said fiber amplifier, said pre-compressor shortening the duration of said optical pulses introduced into said fiber amplifier such that said pulse duration of said optical pulses output by said compressor can be further shortened.

32. The pulsed fiber laser of Claim 31, wherein said pre-compressor comprises a holey fiber.

33. The pulsed fiber laser of Claim 31, wherein said pre-compressor comprises a photonic crystal fiber.

34. The pulsed fiber laser of Claim 31, wherein said pre-compressor comprises a photonic band gap fiber.

35. The pulsed fiber laser of Claim 31, wherein said pre-compressor comprises optics contained in a housing having input and output fibers passing said optical pulses through said optics.

36. The pulsed fiber laser of Claim 35, wherein said optics in said housing are selected from the group consisting of bulk optics and planar waveguide optics.

37. The pulsed fiber laser of Claim 36, wherein said planar waveguide optics comprises a planar waveguide grating.

38. The pulsed fiber laser of Claim 35, wherein said optics in said housing are selected from the group of bulk optical elements comprising gratings, polarizers, waveplates, isolators, mirrors, wedges, and lens.

39. A method of generating short high power optical pulses, said method comprising:

- substantially mode-locking optical modes of a laser cavity to produce an optical signal comprising a plurality of laser pulses having an average pulse width, said optical signal comprising a distribution of frequency components;

- compressing said optical pulses;

- amplifying said compressed optical pulses to produce amplified compressed optical pulses; and

- further compressing said amplified compressed optical pulses subsequent to said amplifying using a dispersive optical element to differentiate between spectral components and introducing different phase shifts to said different spectral components.

40. The method of Claim 39, wherein said compressing said optical pulses prior to amplifying said compressed optical pulses comprises truncating said spectral bandwidth.

41. The method of Claim 39, wherein said compressing said optical pulses prior to amplifying said compressed optical pulses comprises using a dispersive optical element to differentiate between spectral components and introducing different phase shifts to said different spectral components.

42. A pulsed fiber laser comprising:

- a modelocked fiber oscillator outputting optical pulses;

- a fiber amplifier optically connected to said modelocked fiber oscillator, said amplifier amplifying said optical pulses;

- an optical pump source optically connected to said fiber amplifier;

- a pulse compressor optically coupled to receive said amplified optical pulses output from fiber amplifier; and

at least one of

(i) a first optical tap in said optical path between said modelocked fiber oscillator and said fiber amplifier and

a first feedback loop from said first tap to control said modelocked fiber oscillator based on measurement of output from said first optical tap, and

(ii) a second optical tap in said optical path between said fiber amplifier and said compressor and

a second feedback loop from said second tap to control said fiber amplifier based on measurement of output from said first optical tap.

43. The pulsed fiber laser of Claim 42, further comprising a variable optical attenuator between said modelocked fiber oscillator to said fiber amplifier.

44. The pulsed fiber laser of Claim 42, further comprising a pre-compressor between said modelocked fiber oscillator to said fiber amplifier.

45. The pulsed fiber laser of Claim 42, wherein said pre-compressor comprises a spectral filter.

46. The pulsed fiber laser of Claim 42, wherein said pre-compressor comprises a dispersive optical element.

47. The pulsed fiber laser of Claim 42, further comprising a first isolator in said optical path from said oscillator to said fiber amplifier, said first isolator comprising said first tap.

48. The pulsed fiber laser of Claim 42, further comprising a second isolator in said optical path from said fiber amplifier to said compressor, said second isolator containing said second tap.

49. The pulsed fiber laser of Claim 42, further comprising an oscillator pump optical that pumps said modelocked fiber oscillator, said first feedback loop from said first tap controlling said oscillator pump.

50. The pulsed fiber laser of Claim 42, further comprising an amplifier pump optical that pumps said fiber amplifier, said feedback loop from said second tap controlling said amplifier pump.

51. The pulsed fiber laser of Claim 42, further comprising a temperature controller in thermal contact with said modelocked fiber oscillator to adjust operation of said modelocked fiber oscillator, said first feedback loop from said first tap controlling said temperature controller.

52. The pulsed fiber laser of Claim 42, further comprising a temperature controller in thermal contact with said fiber amplifier to adjust operation of said fiber amplifier, said second feedback loop from said second tap controlling said temperature controller.

53. The pulsed fiber laser of Claim 42, further comprising a plurality of modular housings coupled together via optical fiber.

54. The pulsed fiber laser of Claim 53, wherein at least a portion of said modelocked fiber oscillator comprises a housing.

55. A pulsed light source comprising:

- a light source module comprising an optical fiber, said light source module outputting optical pulses;

- an isolator module comprising an optical isolator in a housing having input and output fibers, said input fiber optically coupled to said optical fiber of said light source module, said optical isolator disposed in an optical path connecting said input and output fibers such that said optical pulses introduced into said input fiber are received by said isolator and permitted to continue along said optical path to said output coupler;

- an amplifier module comprising an amplifying medium and having an optical input optically connected to said output fiber of said isolator module to amplify said optical pulses; and

- and a compressor module optically coupled to said amplifier module to compress said optical pulses.

56. The pulsed light source of Claim 55, wherein said light source module further comprises a saturable absorber module comprising a saturable absorber in a housing and optically connected to said optical fiber for said light source module.



57. The pulsed light source of Claim 55, wherein said light source comprises a fiber laser and said fiber for said light source module has gain, said fiber laser further comprising a pair of reflective elements that form a resonant cavity.

58. The pulsed light source of Claim 55, wherein said fiber for said light source module is doped with rare-earth dopants, one of said pair of reflective elements comprises a fiber grating, said laser is pumped by a pump diode, and said laser is modelocked with a saturable absorber.

59. The pulsed light source of Claim 55, wherein said fiber for said light source module is doped with rare-earth dopants selected from the group comprising Er, Yb, Er/Yb, and Nd.

60. The pulsed light source of Claim 59, wherein said fiber for said light source module comprises optical fiber selected from the group consisting of single cladding fiber and double cladding fiber.

61. The pulsed light source of Claim 55, wherein said fiber for said light source module comprises optical fiber selected from the group consisting of polarization maintaining fiber and non-polarization maintaining fiber.

62. The pulsed light source of Claim 55, further comprising an attenuator module comprising attenuation optics in a housing having input and output fibers, said attenuation optics disposed in an optical path between said input and output fibers such that light introduced into said input fiber is attenuated by said attenuation optics and output by said output fiber, said attenuator module disposed in an optical path between said light source module and said amplifier module such that light from said light source module is attenuated by said attenuator module before reaching said amplifier module.

63. The pulsed light source of Claim 62, said attenuation optics comprise a waveplate and a polarization beam splitter cube.

64. The pulsed light source of Claim 55, further comprising a compressor disposed in an optical path between said light source module and said amplifier module such that said optical pulses from said light source module are compressed by said compressor before reaching said attenuator module.

65. The pulsed light source of Claim 64, wherein said compressor is configured to shorten the seed pulse width a sufficient amount to enhance nonlinear effects in said amplifying medium so that the amplified pulse can be compressed in said amplifier yielding a shorter pulse.

66. The pulsed light source of Claim 65, wherein said optical pulses received by said compressor have a corresponding optical spectrum and said compressor comprises a spectral filter that selects a portion of said optical spectrum while selecting a temporal portion of said pulses.

67. The pulsed light source of Claim 66, wherein said compressor comprises a filter selected from the group consisting of a thin-film bandpass filter and a fiber grating.

68. The pulsed light source of Claim 64, wherein said compressor comprises a grating-based pre-compressor.

69. The pulsed light source of Claim 64, wherein said compressor comprises a fiber with tailored dispersion to at least partially compensate for accumulated dispersion.

70. The pulsed light source of Claim 69, wherein said compressor comprises a photonic crystal fiber.

71. The pulsed light source of Claim 55, wherein said modules are optical coupled by fusion spliced fiber.

72. The pulsed light source of Claim 55, further comprising a temperature stabilization system for stabilizing the temperature of at least one of said light source module and said amplifier module.

73. The pulsed light source of Claim 55, further comprising a control system comprising a sensor for monitoring output power from a tap and feedback to selectively adjust at least one of said light source module and said amplifier module.

74. The pulsed light source of Claim 55, further comprising a spectral bandpass filter in said light source to remove the dispersive wave side-peaks in a soliton oscillator.